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Raman Tensor in Semiconductor Crystals

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Abstract:- The present problem has been solved by taking phonon Green`s function . Zubarev equation of motion technique of quantum dynamics has been applied to find Fourier transformed phonon Green` function. Phonon linewidth has been obtained from this method responsible for Raman Tensor. The expression for Raman Tensor has been separated into diagonal and non-diagonal parts. The development of different orders of Raman scattering and their peak intensities have been discussed in low temperature limit in presence of isotopic impurity in low concentration.

Keywords:- Electronic Polarizability , Phonon Green`s Function, Localized Mode, Raman Tensor, Semiconductor.

I. INTRODUCTION

The work on Raman scattering is being continued according to different materials [1]-[3]. Most commonly semiconductor devices have been available for daily uses of this universe. The basic physics in developing the technology is to consider electron and phonon as a carrier in semiconductor crystals. Raman scattering by phonons in a crystal is the inelastic scattering of light caused by the fluctuations in the crystal electronic polarizability induced by the displacements of the atoms from their equilibrium positions [4]. In ideal crystal, normal mode of vibrations having exact eigen state. The localized mode has been formed due to lack of harmonicity in presence of impurity. An interaction of electron with harmonic and localized fields gives the formation of dynamical body. We have to investigate the Raman Tensor under this approach by taking into consideration harmonic Hamiltonian, electron Hamiltonian, electron phonon interaction Hamiltonian and defect Hamiltonian. The work has been done on Raman scattering in impurity-induced anharmonic crystals [5] but in present case of semiconductor crystal electron phonon interaction in presence of isotopic impurity in low temperature limit is taken into consideration to get a different result. The phonon Green`s function is taken to develop the complete characteristics about Raman spectra. Theory of Raman scattering is established by dividing the paper into following sections.

II. FORMULATION OF THE PROBLEM

Raman Tensor $i_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ is given by [5]-[7]

$$i_{\alpha\gamma,\beta\lambda}(\varepsilon_R) = (2\pi)^{-1}\int_{-\infty}^{\infty} dt\, \exp(-i\varepsilon_R t)\langle P_{\beta\lambda}(t)P_{\alpha\gamma}(0)\rangle_T \qquad (1)$$

In above eq.(1) , $\varepsilon_0, \varepsilon_R$, $\varepsilon = \varepsilon_0 + \varepsilon_R$, T , $P_{\beta\lambda}(t)$ are respectively frequency of incident radiation , Raman shift , frequency of scattered light , time ordering , electronic polarizability of the crystal . The electronic polarizability for N cells can be expanded in a Taylor series which is dependent on the normal coordinates $U(kj,t)$ of the crystal in the form as [5], [6]

$$P_{\beta\lambda}(t) = P^0_{\beta\lambda} + N^{1/2}\sum_{k_1 j_1} P_{\beta\lambda}\begin{pmatrix}\vec{k}_1\\ j_1\end{pmatrix} + (1/2)\sum_{k_1 j_1, k_2 j_2} P_{\beta\lambda}\begin{pmatrix}\vec{k}_1 & \vec{k}_2\\ j_1 & j_2\end{pmatrix} U\begin{pmatrix}\vec{k}_1\\ j_1\end{pmatrix}\Big| t\Big) U\begin{pmatrix}\vec{k}_2\\ j_2\end{pmatrix}\Big| t\Big)$$

$$+ (1/6)\sum_{k_1 j_1, k_2 j_2, k_3 j_3} P_{\beta\lambda}\begin{pmatrix}\vec{k}_1 & \vec{k}_2 & \vec{k}_3\\ j_1 & j_2 & j_3\end{pmatrix} U\begin{pmatrix}\vec{k}_1\\ j_1\end{pmatrix}\Big| t\Big) U\begin{pmatrix}\vec{k}_2\\ j_2\end{pmatrix}\Big| t\Big) U\begin{pmatrix}\vec{k}_3\\ j_3\end{pmatrix}\Big| t\Big) + \ldots \qquad (2)$$

In eq.(2) , first term , second term and third term represent Rayleigh scattering , first-order Raman scattering (FORS) , second-order Raman scattering (SORS) and so on respectively .
An eq.(1), with the help of eq.(2) followed by second quantized normal coordinate transformation gives [5]

$$i_{\alpha\gamma,\beta\lambda}(\varepsilon_R)=i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)+i^2_{\alpha\gamma,\beta\lambda}(\varepsilon_R)+i^3_{\alpha\gamma,\beta\lambda}(\varepsilon_R) \quad (3)$$

$i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$, $i^2_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$, $i^3_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ are due to fluctuations in the first-order electronic polarizability , second-order electronic polarizability and third- order electronic polarizability respectively.

In our present situation, impurity and electron phonon interaction are taken in semiconductor crystal. It is convenient to take only fluctuations in first-order electronic polarizability to achieve our aim. Thus, in this case, Raman Tensor $i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ is given as

$$i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)=(1/2\pi)\sum_{k_1,j_1}\sum_{k_1`,j_1`}\int_{-\infty}^{\infty}dt\exp(-i\varepsilon_R t)P^1_{\alpha\gamma,\beta\lambda}\begin{pmatrix}\vec{k}_1 & \vec{k}_1` \\ j_1 & j_1`\end{pmatrix}\left\langle A_{k_1 j_1}(t)A_{k_1` j_1`}(0)\right\rangle \quad (4)$$

This correlation function $\left\langle A_{k_1 j_1}(t)A_{k_1` j_1`}(0)\right\rangle$ may be obtained with the help of [8] as

$$\left\langle A_{k_1 j_1}(t)A_{k_1` j_1`}(0)\right\rangle=-2\int_{-\infty}^{+\infty}\lim_{\omega\to 0}\left(e^{\beta\hbar\varepsilon_R}-1\right)^{-1}\exp(-i\varepsilon_R t)\,\mathrm{Im}.G_{kk`}(\varepsilon_R+i\omega)d\varepsilon_R \quad (5)$$

Thus, our aim is to find imaginary part of Fourier transformed phonon Green`s function $G(\varepsilon_R+i\omega)$.

III. PHONON LINEWIDTH AND PHONON SHIFT

Let us take the following Hamiltonian according to different fields created in semiconductor crystal as [9]-[18]

$$H=H_{op}+H_{oe}+H_D+H_{ep} \quad (6)$$

The various terms in above Hamiltonian eq.(6) are given by

$$H_{op}=(\hbar/4)\sum_k \varepsilon_k\left(A_k^{\ *}A_k+B_k^{\ *}B_k\right) \quad (7a)$$

$$H_{oe}=\hbar\sum_q \varepsilon_q b_q^{\ *}b_q \quad (7b)$$

$$H_D=\hbar\sum_{k_1,k_2}\left[D(\vec{k}_1,\vec{k}_2)A_{k_1}A_{k_2}-C(\vec{k}_1,\vec{k}_2)B_{k_1}B_{k_2}\right] \quad (7c)$$

$$H_{ep}=g\hbar\sum_{k,q} b_Q^{\ *}b_q B_k \quad (7d)$$

H_{op} , H_{oe} , H_D , H_{ep} are harmonic part , electron part , defect part and electron phonon interaction part of Hamiltonian respectively . The symbols of eqs.(7a-7d) are explained in references [9]-[18] .

To achieve our goal, let us consider phonon Green`s function $G_{kk`}(t,t`)=\left\langle\left\langle A_k(t);A_{k`}^{\ *}(t`)\right\rangle\right\rangle$ [19] .The Fourier transformed phonon Green`s function $G_{kk`}(\varepsilon)$ can be obtained by equation of motion technique of quantum dynamics via eqs.(7a-7d) [5],[16]-[20] and Dyson equation approach as

$$G_{kk`}(\varepsilon)=\pi^{-1}\varepsilon_k\eta_{kk`}\left[\varepsilon^2-\bar{\varepsilon}_k^{\ 2}+2i\varepsilon_k\Gamma(kq,\varepsilon)\right]^{-1} \quad (8)$$

Where,

$$\eta_{kk`}=\delta_{kk`}+4C(-\vec{k},\vec{k`})\varepsilon_k^{\ -1}\ ;\ \ \bar{\varepsilon}_k^{\ 2}=\tilde{\varepsilon}_k^{\ 2}+2\varepsilon_k\Delta(kq,\varepsilon) \quad (9)$$

$\bar{\varepsilon}_k$, $\Gamma(kq,\varepsilon)$, $\tilde{\varepsilon}_k$, $\Delta(kq,\varepsilon)$ are respectively denote perturbed mode frequency , phonon half linewidth , renormalized mode frequency and phonon shift . The renormalized mode frequency $\tilde{\varepsilon}_k$ is obtained as

$$\tilde{\varepsilon}_k^{\ 2}=\varepsilon_k^{\ 2}+(2\pi)^{-1}\varepsilon_k\left\{\left\langle\left[M_{kq}(t),B_{k`}^{\ *}(t`)\right]\right\rangle+\left\langle\left[M_{kq}(t),A_{k`}^{\ *}(t`)\right]^0\right\rangle+4\varepsilon_k^{\ -1}\sum_{k_1}C(\vec{k},-\vec{k}_1)\left\langle\left[M_{kq}(t),B_{k`}^{\ *}(t`)\right]^0\right\rangle\right.$$

$$\left.+8(\varepsilon^2-\varepsilon_k^{\ 2})\varepsilon_k^{\ -1}C(-\vec{k},\vec{k`})-2g\varepsilon_k^{\ -1}\sum_q\left\langle\left[M_{kq}(t),b_Q^{\ *}b_q\right]^0\right\rangle\right\}_{t=t`} \quad (10)$$

Where,

$$M_{kq}(t) = 4\pi \sum_{k_1} R\left(-\vec{k}, \vec{k}_1\right) A_{k_1} - 2\pi L_{kq}(t) \tag{11}$$

With,

$$R\left(\vec{k}_1, \vec{k}_2\right) = \varepsilon_{k_2} \varepsilon_{k_1}{}^{-1} C\left(\vec{k}_1, \vec{k}_2\right) + D\left(\vec{k}_1, \vec{k}_2\right) + 4 \sum_{k_2`} C\left(-\vec{k}_1, \vec{k}_2`\right) D\left(-\vec{k}_2`, \vec{k}_2\right) \varepsilon_{k_1}{}^{-1} \tag{12a}$$

$$L_{kq}(t) = g \sum_{q} \left\{ \varepsilon_q \left(b_q{}^* b_q + b_Q{}^* b_q \right) + g\left(b_q{}^* b_q B_k + b_Q{}^* b_q B_k \right) \right\} \tag{12b}$$

This method gives response function $P(kq, \varepsilon)$ as

$$P(kq, \varepsilon) = 8 \sum_{k_1} R\left(\vec{k}_1, -\vec{k}\right) R^*\left(\vec{k}_1, -\vec{k}\right) \varepsilon_{k_1} \left(\varepsilon^2 - \tilde{\varepsilon}_{k_1}{}^2 \right)^{-1} + 4g^2 \left(N_q + N_Q \delta_{QQ`} \right) \left( \varepsilon_q{}^2 + g^2 \tilde{n}_k \delta_{kk`} \right) \left(\varepsilon - 2\varepsilon_q \right)^{-1} \tag{13}$$

Where,

$$N_q = \left\langle b_q{}^* b_q \right\rangle \ , \ N_Q = \left\langle b_Q{}^* b_Q \right\rangle \ , \ \tilde{n}_k = \left\langle B_k{}^* B_k \right\rangle \tag{14}$$

The response function $P(kq, \varepsilon)$ gives the phonon linewidth $\Gamma(kq, \varepsilon)$ and phonon shift $\Delta(kq, \varepsilon)$ through following relation as

$$P(kq, \varepsilon + i\omega) = \Delta(kq, \varepsilon) - i\Gamma(kq, \varepsilon) \qquad \text{where } \omega \to 0^+ \tag{15}$$

Phonon linewidth $\Gamma(kq, \varepsilon)$ is contributed by defect part $\Gamma^D(kq, \varepsilon)$ and electron phonon interaction part $\Gamma^{ep}(kqQ, \varepsilon)$ as

$$\Gamma(kq, \varepsilon) = \Gamma^D(kq, \varepsilon) + \Gamma^{ep}(kq, \varepsilon) \tag{16}$$

Where,

$$\Gamma^D(kq, \varepsilon) = 8\pi\omega(\varepsilon) \sum_{k_1} R\left(\vec{k}_1, -\vec{k}\right) R^*\left(\vec{k}_1, -\vec{k}\right) \varepsilon_{k_1} \delta\left(\varepsilon^2 - \tilde{\varepsilon}_{k_1}{}^2 \right) \tag{17a}$$

$$\Gamma^{ep}(kqQ, \varepsilon) = 4g^2 \left(N_q + N_Q \delta_{QQ`} \right) \left( \varepsilon_q{}^2 + g^2 \tilde{n}_k \delta_{kk`} \right) \delta\left(\varepsilon - 2\varepsilon_q \right) \tag{17b}$$

Let us evaluate again Fourier transformed phonon Green`s function with the help of equation of motion technique of quantum dynamics by differentiating it twice with respect to t with the help of Hamiltonian eq.(6) as [5],[16]-[20]

$$G_{kk`}(\varepsilon) = 2^{-1} \pi^{-1} \varepsilon_k \tilde{\varepsilon}_k{}^{`-1} \left(1 + 4C\left(\vec{k}`, -\vec{k}\right) \varepsilon_k{}^{-1} \right) \left[ \left( \varepsilon - \tilde{\varepsilon}_k{}` \right)^{-1} - \left(\varepsilon + \tilde{\varepsilon}_k{}` \right)^{-1} \right] - 2\pi^{-1} g^2 \sum_{q} N_Q \left[ \left\{ \left( \tilde{\varepsilon}_k{}` - 2\varepsilon_q \right)^2 - \varepsilon_k{}^2 \right\}^{-1} \left(\varepsilon - \tilde{\varepsilon}_k{}` \right)^{-1} + \left\{ \left( \tilde{\varepsilon}_k{}` + 2\varepsilon_q \right)^2 - \varepsilon_k{}^2 \right\}^{-1} \left(\varepsilon + \tilde{\varepsilon}_k{}` \right)^{-1} + \left( \varepsilon_k - 2\varepsilon_q \right) \varepsilon_k{}^{-1} \left\{ \left( \varepsilon_k - 2\varepsilon_q \right)^2 - \tilde{\varepsilon}_k{}^{`2} \right\}^{-1} \left\{ \left(\varepsilon - 2\varepsilon_q \right) + \varepsilon_k \right\}^{-1} + \left(\varepsilon_k + 2\varepsilon_q \right) \varepsilon_k{}^{-1} \left\{ \left(\varepsilon_k + 2\varepsilon_q \right)^2 - \tilde{\varepsilon}_k{}^{`2} \right\}^{-1} \left\{ \left(\varepsilon - 2\varepsilon_q \right) - \varepsilon_k \right\}^{-1} \right] \tag{18}$$

Where,

$$\tilde{\varepsilon}_k{}^{`2} = \varepsilon_k{}^2 + 4\varepsilon_k \sum_{k_1} \left[C\left(\vec{k}_1, -\vec{k}\right) + D\left(\vec{k}_1, -\vec{k}\right) + 4C\left(\vec{k}_1, -\vec{k}\right) D\left(\vec{k}_1, -\vec{k}_1\right) \right] \tag{19}$$

In low impurity concentration, N_Q, N_q , $\tilde{n}_k$ are evaluated with the help of Green's function eq.(18) following [21] as

$$\tilde{n}_k = 64\pi^{-1} g^2 k_B{}^2 T^2 \varepsilon_k \tilde{\varepsilon}_k{}^{`-2} \sum_{q} \varepsilon_q{}^2 A_{kQ} \left( \tilde{\varepsilon}_k{}^{`2} - \tilde{\varepsilon}_Q{}^{`2} \right)^{-2} \left( \varepsilon_k{}^4 - 8\varepsilon_k{}^2 \varepsilon_q{}^2 - 2\varepsilon_k{}^2 \tilde{\varepsilon}_k{}^{`2} - 8\tilde{\varepsilon}_k{}^{`2} \varepsilon_q{}^2 + 16\varepsilon_q{}^4 + \tilde{\varepsilon}_k{}^{`4} \right) C_{kqk}(-) C_{kqk}(+) D_{kqk}(-) D_{kqk}(+) \tag{20a}$$

$$N_Q = 2\pi^{-1} k_B T \varepsilon_k \tilde{\varepsilon}_k{}^{`-2} A_{kQ} B_{kQ} C_{kqk}(-) C_{kqk}(+) D_{kqk}(-) D_{kqk}(+) E_{kqQ}(-) E_{kqQ}(+) \tag{20b}$$

$$N_q = 2\pi^{-1} k_B T \varepsilon_k \tilde{\varepsilon}_k{}^{`-2} A_{kq} B_{kq} C_{kqk}(-) C_{kqk}(+) D_{kqk}(-) D_{kqk}(+) E_{kqq}(-) E_{kqq}(+) \tag{20c}$$

Where,

$$A_{km}=\left(\tilde{\varepsilon}_k^{\,`2}+\tilde{\varepsilon}_m^{\,`2}\right);\quad B_{km}=\left(\tilde{\varepsilon}_k^{\,`2}-\tilde{\varepsilon}_m^{\,`2}\right)^{-4};\qquad \text{Where, m = q, Q} \tag{21a}$$

$$C_{kqk}(\mp)=\left\{\left(\tilde{\varepsilon}_k^{\,`}\mp 2\varepsilon_q\right)^2-\varepsilon_k^{\,2}\right\}^{-1};\quad D_{kqk}(\mp)=\left\{\left(\varepsilon_k\mp 2\varepsilon_q\right)^2-\tilde{\varepsilon}_k^{\,`2}\right\}^{-1} \tag{21b}$$

$$E_{kqm}(\mp)=\left\{\left(\varepsilon_k\mp 2\varepsilon_q\right)\pm\tilde{\varepsilon}_m^{\,`}\right\}^{-2};\ m=q,Q \tag{21c}$$

In this theoretical approach, eq.(17b) gets a new form with the help of above eqs.(20a-20c) as

$$\Gamma^{ep`}(kqQ,\varepsilon)=g^2T\left(1+g^4T^2L(kqkQ)\right)A_{kq}B_{kq}J(kqk)E_{kqq}(-)E_{kqq}(+)\delta\left(\varepsilon-2\varepsilon_q\right) \tag{22}$$

$$\Gamma^{ep``}(kqQ,\varepsilon)=g^2T\left(1+g^4T^2L(kqkQ)\right)A_{kQ}B_{kQ}J(kqk)E_{kqQ}(-)E_{kqQ}(+)\delta\left(\varepsilon-2\varepsilon_q\right) \tag{23}$$

Where,

$$J(kqk)=8\pi^{-1}k_B\varepsilon_k\tilde{\varepsilon}_k^{\,`-2}\varepsilon_q^{\,2}C_{kqk}(-)C_{kqk}(+)D_{kqk}(-)D_{kqk}(+) \tag{24a}$$

$$L(kqkQ)=64\pi^{-1}k_B^{\,2}\tilde{\varepsilon}_k^{\,`-2}\sum_q\ \varepsilon_k A_{kQ}\left(\tilde{\varepsilon}_k^{\,`2}-\tilde{\varepsilon}_Q^{\,`2}\right)^{-2}\left(\ \varepsilon_k^{\,4}-8\varepsilon_k^{\,2}\varepsilon_q^{\,2}-2\varepsilon_k^{\,2}\tilde{\varepsilon}_k^{\,`2}-8\tilde{\varepsilon}_k^{\,`2}\varepsilon_q^{\,2}\right.$$
$$\left.+16\varepsilon_q^{\,4}+\tilde{\varepsilon}_k^{\,`4}\ \right)C_{kqk}(-)C_{kqk}(+)D_{kqk}(-)D_{kqk}(+) \tag{24b}$$

IV. RAMAN TENSOR

Raman Tensor eq. (4) can be solved by substituting imaginary part of Phonon Green`s function eq. (8) in it through eq.(5) as

$$i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)=\left(2/\pi^2\right)\sum_{k_1,j_1}\sum_{k_1`,j_1`}\int_{-\infty}^{\infty}dt\exp(-i\varepsilon_R t)P^1_{\alpha\gamma,\beta\lambda}\begin{pmatrix}\vec{k}_1 & \vec{k}_1`\\ j_1 & j_1`\end{pmatrix}\eta_{kjk`j`}\int_{-\infty}^{+\infty}\left(e^{\beta\hbar\varepsilon_R}-1\right)^{-1}\left(\varepsilon_R^{\,2}-\bar{\varepsilon}_k^{\,2}\right)^{-2}$$
$$\Gamma(kq,\varepsilon_R)d\varepsilon_R \tag{25}$$

The above eq.(25) for Raman Tensor $i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ can be separated into diagonal part $i^{1\ d}_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ and non-diagonal part $i^{1\ nd}_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ as [5]

$$i^1_{\alpha\gamma,\beta\lambda}(\varepsilon_R)=i^{1\ d}_{\alpha\gamma,\beta\lambda}(\varepsilon_R)+i^{1\ nd}_{\alpha\gamma,\beta\lambda}(\varepsilon_R) \tag{26}$$

Where,

$$i^{1\ d}_{\alpha\gamma,\beta\lambda}(\varepsilon_R)=i^{1\ d}_{\alpha\gamma,\beta\lambda_D}(\varepsilon_R)+i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep`}}(\varepsilon_R)+i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep``}}(\varepsilon_R) \tag{27a}$$

And,

$$i^{1\ nd}_{\alpha\gamma,\beta\lambda}(\varepsilon_R)=4C\left(-\vec{k},\vec{k}`\right)\varepsilon_k^{-1}\left[i^{1\ d}_{\alpha\gamma,\beta\lambda_D}(\varepsilon_R)+i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep`}}(\varepsilon_R)+i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep``}}(\varepsilon_R)\right] \tag{27b}$$

In eq.(27a) and eq. (27b), D and ($ep`$, $ep``$) are defect part and electron phonon interaction part respectively .

The defect contribution $i^{1\ d}_{\alpha\gamma,\beta\lambda_D}(\varepsilon_R)$ and electron phonon interaction contributions $i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep`}}(\varepsilon_R)$, $i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep``}}(\varepsilon_R)$ of eq.(27a) and eq.(27b) are given by

$$i^{1\ d}_{\alpha\gamma,\beta\lambda_D}(\varepsilon_R)=16\hbar^{-1}k_BT\sum_{kj}\ P^1_{\alpha\gamma,\beta\lambda}\begin{pmatrix}\vec{k} & -\vec{k}\\ j & j\end{pmatrix}R\left(-\vec{k},\vec{k}\right)R^*\left(-\vec{k},-\vec{k}\right)\varepsilon_k\tilde{\varepsilon}_k^{\,-2}\left(\tilde{\varepsilon}_k^{\,2}-\bar{\varepsilon}_k^{\,2}\right)^{-2} \tag{28a}$$

$$i^{1\ d}_{\alpha\gamma,\beta\lambda_{ep`}}(\varepsilon_R)=\pi^{-2}\hbar^{-1}g^2k_BT^2\varepsilon_q^{-1}\sum_{k,j}\ P^1_{\alpha\gamma,\beta\lambda}\begin{pmatrix}\vec{k} & -\vec{k}\\ j & j\end{pmatrix}\left(1+g^4T^2L(kqkQ)\right)A_{kq}B_{kq}J(kqk)$$
$$E_{kqq}(-)E_{kqq}(+)\left(4\varepsilon_q^{\,2}-\bar{\varepsilon}_k^{\,2}\right)^{-2} \tag{28b}$$

$$i^{1}_{\alpha\gamma,\beta\lambda}{}^{d}_{ep^{``}}(\varepsilon_R) = \pi^{-2}\hbar^{-1}g^{2}k_B T^{2}\varepsilon_q{}^{-1}\sum_{k,j} P^{1}_{\alpha\gamma,\beta\lambda}\begin{pmatrix} \vec{k} & -\vec{k} \\ j & j \end{pmatrix}\left(1+g^{4}T^{2}L(kqkQ)\right)A_{kQ}B_{kQ}J(kqk)$$

$$E_{kqQ}(-)E_{kqQ}(+)\left(4\varepsilon_q{}^{2}-\bar{\varepsilon}_k{}^{2}\right)^{-2} \qquad (28c)$$

The Raman Tensor $i^{1}_{\alpha\gamma,\beta\lambda}(\varepsilon_R)$ obtained from this work gives the information about intensity of Raman scattering per unit solid angle through the following equation as [5],[6]

$$I(\varepsilon_R) = \left(\varepsilon_0{}^{4}/2\pi c^{3}\right)\sum_{\alpha\beta,\gamma\lambda} n_\alpha n_\beta i_{\alpha\gamma,\beta\lambda}(\varepsilon_R)E^{-}_{\gamma}E^{+}_{\lambda} \qquad (29)$$

V. CONCLUSIONS

The present Green`s function approach provide the different orders of Raman scattering. The renormalized mode, two exciton bound state are the excitations produced in defect part and in electron phonon interaction part respectively. Raman Tensor is separated in the form of diagonal and non-diagonal parts. These are dependent on defect part and electron phonon interaction part. The first order Raman scattering (FORS) and second order Raman scattering (SORS) are found to produce by renormalized mode in defect part and exciton bound state by two successive FORS in electron phonon interaction part respectively. The creation of two exciton bound state gives the formation of stoke lines in electron phonon interaction field. In FORS both stoke and antistoke lines are generated by creating and annihilating renormalized mode frequency respectively. It is also found from theory that these orders depend on temperature as T in defect part, T^2 and T^4 in electron phonon interaction part. Raman Tensor reflects the intensity through excitations produced in scattering processes. In the limit, renormalized mode and the two exciton bound state are identical with perturbed mode frequency, the Raman peaks of first and second orders become sharp.In addition to this, asymptotic nature of intensity of peaks in second order may also be occur when $\tilde{\varepsilon}_k{}^{`} = \tilde{\varepsilon}_q{}^{`}, \tilde{\varepsilon}_Q{}^{`}$ ; $\tilde{\varepsilon}_k{}^{`} \mp 2\varepsilon_q = \varepsilon_k$; $\varepsilon_k \mp 2\varepsilon_q = \tilde{\varepsilon}_k{}^{`}$ , $\varepsilon_k \mp 2\varepsilon_q = \mp\tilde{\varepsilon}_q$ , $\mp\tilde{\varepsilon}_Q{}^{`}$.

The peaks are due to defect term is not only found to be temperature dependent but still influenced by electron phonon interaction through renormalized mode frequency. This work tends to defect dependent part of work of reference [5] when we take only harmonic and defect terms in Hamiltonian. In very low impurity concentration, diagonal part contributes to Raman scattering in comparison to non-diagonal part. This theory concludes that in absence of impurity, electron phonon interaction plays prominent role to give Raman spectra. The intensity of peaks in SORS depends as g^2 and g^6 on electron phonon coupling constant. This shows that the temperature variation T^4 strongly couple electron and phonon in comparison to T^2 dependence. The temperature dependence of Raman spectra can also be seen in reference [22].

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